Natural Radioactivity Hazard Assessment on Soil in Kassala Town-Sudan

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Abstract

Human beings have always been exposed to natural radiation, which is mainly due to the activity concentration of primordial radio nuclides. In this study, measure the concentration of natural activity radiation, absorbed dose rate, annual effective dose (indoor/outdoor) and assessment of radiation hazard index are measured for some soil sample from various geographical locations in Kassala Town-Kassala State – Sudan , for the elements ^{226}Ra, ^{232}Th and ^{40}K, using gamma-ray spectrometry. The study conduct to the average concentration for^{226}Ra, ^{232}Th and ^{40}Kwere found to be 18.19 Bq/Kg, 19.56 Bq/Kg and732.37 Bq/Kg respectively. The calculated average absorbed dose rate was 50.75nGy/h, annual effective dose were0.25mSv/y(indoor), 0.06mSv/y(outdoor) and the radiation hazard index was 0.29. The study conclude that the average concentration of all elements in the study is less than the average worldwide ^{226}Ra =35 Bq/Kg),(^{232}Th=30 Bq/Kg) except ^{40}K(^{40}K=400 Bq/Kg) and also the absorbed dose rate and annual effective dose (indoor/outdoor) are less than the average worldwide(60 nGy/h), (0.41mSv/y(indoor), (0.07mSv/y(outdoor). The assessment of radiation hazard index to the soil of Kassala Town is more less than the standard ($\leq$ 1).

Keywords: Natural Radioactivity Hazard**,** Soil sample,Gamma Spectrometry, Kassala**.**

المستخلص

لقد ظلت البشرية تتعرض إلى تأثير الإشعاع الطبيعي الناتج بصورة رئيسة من تركيز النشاط للنويدات المشعة، في هذه الدراسة تم قياس تركيز النشاط الإشعاعي وحساب معدل متوسط الجرعة الممتصة، والجرعة الفعّالة السنوية بالداخل والخارج وتقييم الخطر الإشعاعي لعينات من تربة مدينة كسلا- ولاية كسلا- السودان، لمواقع جغرافية مختلفة للعناصر ^{226}Ra،^{232}Th و ^{40}K ، باستخدام مطيافية أشعة غاما، توصلت الدراسة إلى أنّ تراكيز متوسط النشاط الإشعاعي لكل من ^{226}Ra،^{232}Th و^{40}K كانت Bq/Kg 18.19، Bq/Kg 19.56 و732.37Bq/Kg،ومعدل متوسط الجرعة الممتصة يساوي 50.75nGy/h والجرعة الفعّالة السنوية تساوي 0.25mSv/y (بالداخل) و0.06 msv/y (بالخارج). كما أنّ قيمة مؤشر الخطر الإشعاعي تساوي 0.29. خلصت الدراسة على أن متوسط تراكيز كل العناصر المدروسة بالنسبة لتربة مدينة كسلا ولكل المواقع الجغرافية أقل من المتوسط العالمي((^{226}Ra =35Bq/Kg، ^{232}Th= (30Bq/Kg) و (^{40}K=400Bq/Kg) عدا ^{40}K ، وكذلك معدل متوسط الجرعة الممتصة ومتوسط الجرعة الفعّالة السنوية بالداخل والخارج أقل من المتوسط العالمي((nGy/h 60،0.41 mSv/y)(بالداخل))(0.07 mSv/y(بالخارج))

أما بالنسبة لتقييم الخطر الإشعاعي على تربة مدينة كسلا نلاحظ أنه أقل بكثير جداً من قيمة الخطر القياسي((≤ 1.)

Introduction

Radiation is energy in the form of waves or streams of particles, there are many kinds of radiation all around us, when people hear the word radiation, they often think of atomic energy, nuclear power and radioactivity, but radiation has many other forms, Sound and visible light are familiar forms of radiation; other types include ultraviolet radiate (that produces a suntan), infrared radiation (a form of heat energy), and radio and television signal. Some atoms are naturally stable while others are unstable. Atoms with unstable nuclei which spontaneously transform, releasing energy in the form of radiation are known as radio nuclides. This energy can interact with other atoms and ionize them. Ionization is the process by which atoms become positively or negatively charged by gaining or losing electrons. There are two forms of radiation non-ionizing and ionizing. Non-ionizing radiation has less energy than ionizing radiation; it does not possess enough energy to produce ions. Examples of non-ionizing radiation are visible light, infrared, radio waves, microwaves, and sunlight. Ionizing radiation is capable of knocking electrons out of their orbits around atoms, upsetting the electron/proton balance and giving the atom a positive charge. Electrically charged molecules and atoms are called ions. Ionizing radiation includes the radiation that comes from both natural and man-made radioactive materials. Alpha radiation ,Beta radiation and gamma radiation (Canadian Nuclear Safety Commission, Catalogue ,2012).

Sources of Radiation:

The sources of radiation are broadly divided into two main types, namely the natural sources and artificial sources.

Natural Sources of radiation:

The assessment of the radiation doses in human beings from natural sources is special importance because natural radiation is by far the largest contributor to the collective dose received by the world population.

The natural radiation sources are classified into: (a) external sources of extraterrestrial origin (that is, cosmic radiation) and radiation of terrestrial origin (that is, the radioactive nuclides present in the crust of the earth, in building materials and in air). (b)internal sources, comprising the naturally occurring radio nuclides that are taken into the human body (UNSCEAR , 1988).

Artificial Sources:

The uses of radiation have increased significantly over the past decades as scientists learned to use the energy of the atom for a wide variety of purposes, from military to medical applications (e.g. cancer treatment), and from electricity production to domestic applications (e.g. smoke detectors). These and other artificial sources add to the radiation dose from natural sources for both individuals and the global population.

Individual doses from artificial sources of radiation vary greatly. Most people receive a relatively small dose from such sources but a few receive many times the average. Artificial sources of radiation are generally well controlled by radiation protection measures (UNSCEAR ,1988).

Effects of Radiation:

Radiation can effect health through biological mechanism, It can produce effects at the level of cells, causing their death or modification usually because of direct damage to DNA.

Radio nuclides can be transferred to plants and then to animals from rocks and mineral present in the soil and water.(UNSCEAR,2008).

Human beings have always been exposed to natural radiation, which is mainly due to the activity concentration of primordial radio nuclides $^{238}U(^{226}Ra)$ series, ^{232}Th series and ^{40}K that present in the earth's crust, in building materials, in air, water, foods and in the human body itself.

Radiation Doses:

When ionizing radiation penetrates the human body or an object, it deposits energy. The energy absorbed from exposure to radiation is called an absorbed dose. The absorbed dose is measured in a unit called the Gray (Gy). A dose of one gray is equivalent to a unit of energy (Joule) deposited in a Kilogram of a substance. However, the biological effects per unit of absorbed dose varies with the type of radiation and the part of the body exposed. To take account of those variations, a weighted quantity called the effective dose is used and its unit is the Sievert (Sv).

In addition a radioactive source is described by its activity ,which is the number of nuclear disintegrations per unit of time. The unit of activity is the Becquerel (Bq). One Becquerel is one disintegration per second. Types of ionizing radiation differ in the way in which they interact with biological materials, so that equal absorbed doses (meaning equal amounts of energy deposited) do not necessarily have equal biological effects. For instance, 1Gy to tissue from alpha radiation is more harmful than 1 Gy from beta radiation because an alpha particle, being slower and more heavily charged, loses its energy much more densely along its path. So in order to put all the different types of ionizing radiation on an equal basis with respect to their potential for causing harm, we need another quantity, which is called the equivalent dose. It is expressed in a unit called the sievert, symbol Sv. Submultiples of the Sievert are commonly used, such as the milli sievert, mSv, which is one-thousandth of a Sievert.

Absorbed Dose Rate

The measured activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K are converted into doses (nGy h^{-1} per Bq kg^{-1}) by applying the factors 0.462, 0.604 and 0.042 for Radium , thorium and potassium, respectively. These factors are used to calculate the total absorbed gamma dose rate in air at one meter above the ground level using the following equation:

$D_R = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K$ (1)

Where the numerical values 0.462, 0.621 and 0.417 are the dose conversion factors for converting activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K into doses.

The Annual Effective Dose Equivalent (H_E)

The annual effective dose equivalent rate H_E was calculated from the absorbed dose by applying the dose conversion factor of 0.7 $Sv{\cdot}Gy^{-1}$ with an outdoor occupancy factor of 0.2 and 0.8 for indoor, The effective dose rate in units of $mSv.y^{-1}$ was calculated by following equation:

$$H_E = D_R \times T \times F \qquad (2)$$

Where D_R is the calculated dose rate (in $nGy.h^{-1}$), T is the outdoor occupancy time (24 h x 365.25 days x 0.2 = 1,753 $h.y^{-1}$), and F is the conversion factor (0.7 $Sv.Gy^{-1}$).

$H_{E,\ Outdoor} = D_R\ (nG{\cdot}h^{-1}) \times 8760\ (h{\cdot}y^{-1}) \times 0.7 \times (10^3 mSv/nGy\ \ 10^9) \times 0.2$ (3)

$H_{E,\,Outdoor} = D_R \times 1.226 \times 10^{-3}\ (mSv{\cdot}y^{-1})$ (4)

$H_{E,\,Indoor} = D_R\ (nG{\cdot}h^{-1}) \times 8760\ (h{\cdot}y^{-1}) \times 0.7 \times (10^{3} mSv/nGy\ \ 10^{9}) \times 0.8$ **(5)**

$H_{E,\,Indoor} = D_R \times 4.905 \times 10^{-3}\ (mSv{\cdot}y^{-1})$ (6)

To estimate annual effective doses, account must be taken of (a) the conversion coefficient from absorbed dose in air to effective dose and (b) the indoor occupancy factor. The average numerical values of those parameters vary with the age of the population and the climate at the location considered. A report by the UNSCEAR Committee , used 0.7 $Sv{\cdot}Gy^{-1}$ for the conversion coefficient from absorbed dose in air to effective dose received by adults and 0.8 for the indoor occupancy factor, *i.e.* the fraction of time spent indoors and outdoors is 0.8 and 0.2, respectively. The resulting worldwide average of the annual effective dose is 0.48 mSv, with the results for individual countries being generally within the 0.3 - 0.6 mSv range. For children and infants, the values are about 10% and 30% higher, in direct proportion to an increase in the value of the conversion coefficient from absorbed dose in air to effective dose.

Radiation Hazards Indexes:

Soils and aggregate materials can be used in industries and building constructions, the γ-ray radiation hazards due to the specified radio nuclides were assessed by three different indices.

In comparing the specific activity of samples containing different amounts of ^{226}Ra, ^{232}Th and ^{40}K, it is necessary to introduce the term radium equivalent activity (Ra_{eq}). It was defined as a single quantity that represents the combined specific activities of ^{226}Ra, ^{232}Th and ^{40}K, and develops a numerical indicator of an external dose to public and internal dose due to radon and its daughters Equation (7) is used to calculate radium equivalent activity and stated the value of 370 $Bq.kg^{-1}$ as the maximum allowed value for public dose considerations according to:

$A_{Ra} + 1.43A_{Th} + 0.077A_{K},$ (7)

Where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$,respectively.

The external hazard index (H_{ex}) is a radiation hazard index defined to evaluate the indoor radiation dose rate due to the external exposure to γ-radiation from the natural radio nuclides in the construction building materials of dwellings. This index value must be less than unity to keep the radiation hazard insignificant, i.e. the radiation exposure due to the radioactivity from construction materials to be limited to 1.5 $mSv.y^{-1}$or 1.0$mSv.y^{-1}$, based on the formula:

$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810) \leq 1$ (8)

Where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 $Bq.kg^{-1}$).

Materials and Methods

The Study Area

Kassala Town is located to the eastern part of the Sudan, in Kassala State. The state lies between latitudes 14° 45\ and 17° 15\ N, and longitudes of 34° 40\ and 37° E, in an area of 42330

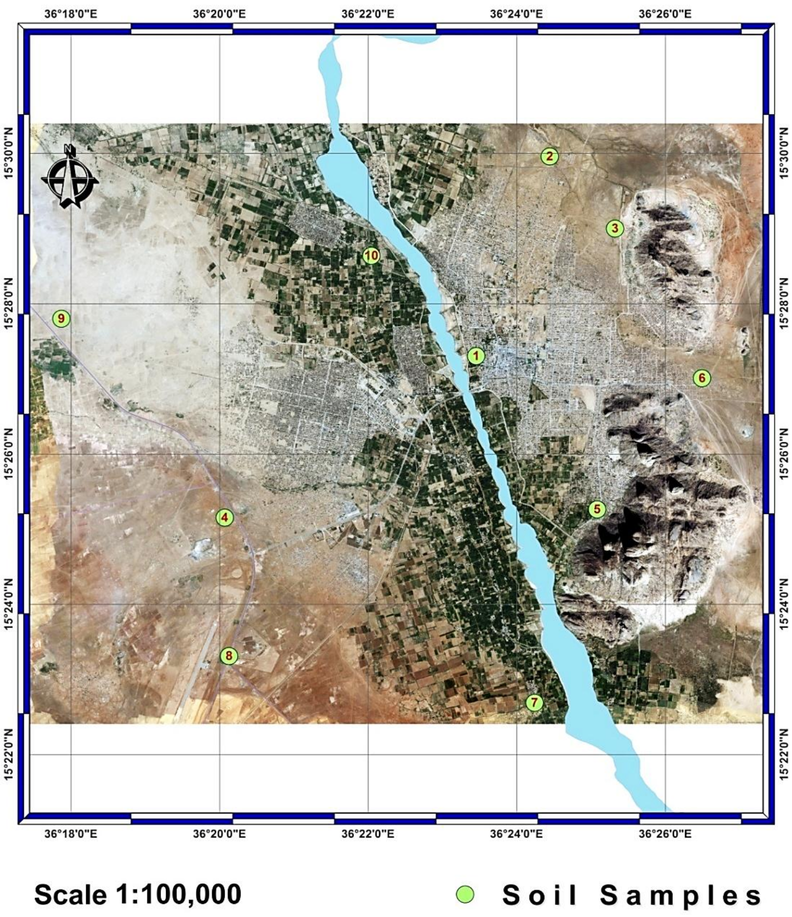
km^2. Kassala Town is the capital of the state. The town is located at latitude at a $15^o\ 27^\backslash$ N and longitude $36^o\ 24^\backslash$ E and at a distance of 625 km from Khartoum.

Sample Collection and preparation:

To measure radioactivity in soil, thirty samples of soil were collected from ten locations. Each soil sample was collected from a large area covering the town geographically. The ten locations were chosen in away to cover the town as follows: North , South , West , East , North east, North west, South east , South west, Centre and the extreme far North west. From each location three samples were taken. One sample is from residential area , another sample is from open area and the third sample is from an area of natural plants. The GPS device was used to determine the geographical position of each point of the samples.The samples were collected soil surface (about 0–10 cm).

Sample Preparation has been done at Sudan atomic energy commission in the lab of food and environment monitoring. The samples were dried and crushed in carful way such that no contamination could happen, after that a weight 500g taken from each sample using highly sensitive balance. This packaged in a plastic bottle In order to have reasonable result the sample kept packaged for a period of four weeks, this can insure that the samples reach the equilibrium between uranium and his daughters. After that Gamma-ray spectrometry detector was used to measure the activity concentration for each sample.

igure : Sample locations in Kassala Town



In the measurement of these samples, we used High Purity Germanium (HpGe) detector with sensitive material type P. This has relative efficiency 37% compare to NaI standard detectors and resolution for Gamma lines 1.33 Mev were 1850. Moreover, system attached to multichannel analyzer that can represents the values of energy between 3 to 10000 Kev, it also attached to software on computer disk from Russian company BSI for radiation detection instrument .A typical analog HPGe detector-based gamma spectroscopy system consists of a HPGe detector, high voltage power supply, preamplifier (which is usually solid as part of the detector), amplifier, Analogue to Digital Converter (ADC), and Multi- Channel Analyzer (MCA).

Calculations:

The activity concentrations of the natural radio nuclides in the measured samples (AS) should be computed using the following relation

$AS\ (Bq \cdot kg^{-1}) = Ca/\varepsilon\ Pr\ Ms$ (9)

Where Ca is the net gamma counting rate (counts per second), ε the detector efficiency of the specific γ-ray, Pr the absolute transition probability of Gamma-decay and Ms is the mass of the sample (Kg).

Absorbed Dose Rate

From the equation (1) the absorbed dose is given by:

$D_R = 0.462\ A_{Ra} + 0.604\ A_{Th} + 0.0417\ A_K (nGy/h)$ (10)

Where the numerical values 0.462, 0.621 and 0.417 are the dose conversion factors for converting activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K into doses.

The Annual Effective Dose Equivalent (H_E)

From the equation(2) the annual effective doe are given by:

$H_{E,\ Outdoor} = D_R \times 1.226 \times 10^{-3}$ (mSv/y) (11)

$H_{E,\ Indoor} = D_R \times 4.905 \times 10^{-3}$ (mSv/y) (12)

Radiation Hazards indexes

From the equation (8) the radiation hazard index is given by:

$Ra_{eq} = A_{Ra} + 1.43A_{Th} + 0.077A_K$,(Bq/Kg) (13)

Where, Ra_{eq} is the radium equivalent activity ,A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ respectively.

$H_{ex} = (A_{Ra}/370) + (A_{Th}/259) + (A_K/4810) \leq 1$ (14)

Where A_{Ra}, A_{Th} and A_K are the specific activities of ^{226}Ra, ^{232}Th and ^{40}K in $Bq.kg^{-1}$ respectively. The maximum value of H_{ex} equal to unity corresponds to the upper limit of Ra_{eq} (370 $Bq.kg^{-1}$).

Results And Discussion

The activity concentration for all samples from the different town locations were obtained directly from the detector as shown. The following tables the average activity concentration for each element in all locations in the overall average for the town were calculated . (table 1 – 21).

From table (1) it can be seen that, there are some differences in the activity concentrations for the studied elements between three results for each element. These results are taken from three types of areas, for example sample S_1, S_4 ,S_7 S_{10}, S_{13} ,S_{16} ,S_{19} ,S_{22} ,S_{25} and$S_{28}$from residential area, S_2 , S_5 ,S_8 ,S_{11} ,S_{14} ,S_{17} S_{20} ,S_{23} , and$S_{29}$from an area with plants and S_3 ,S_6 S_9 ,S_{12} ,S_{15} ,S_{18} ,S_{21} ,S_{24} ,S_{26} and S_{27} are from an open area. From this table it is found that ^{226}Ra, is highest in plant area (37Bq in residential area(1880Bq/Kg) and lowest in open area(1140Bq/Kg),for ^{232}Th,is highest/Kg),while it lowest in the open area (14.7Bq/Kg),for ^{40}K, highest in the plant area(59Bq/Kg)and lowest in the open area(13Bq/Kg). From table (2) ^{226}Ra is highest in the plant area (17.8Bq/Kg) and lowest in the open area(6.7Bq/Kg).^{40}K is highest in the plant area(600Bq/Kg) and lowest in the open area(320Bq/Kg). ^{232}Th is highest in plant area(5.1Bq/Kg) and lowest in the residential area(2.7Bq/Kg).From table (3)^{226}Ra is highest in open area(23.3Bq/Kg)and lowest in plant area(13.7Bq/Kg). ^{40}K is highest in plant area(730Bq/Kg) and lowest in residential area. ^{232}Th is highest in the open area(4.9Bq/Kg) and lowest in the plant area(2.6Bq/Kg).From table (4) ^{226}Ra is highest in plant area(27.2Bq/Kg) and lowest in residential area(12.7Bq/Kg). ^{40}K is highest in plant area(1320Bq/Kg) and lowest in residential area(442Bq/Kg). ^{232}Th is highest in plant area(30Bq/Kg) and lowest in open area(1.9Bq/Kg).From table(5)^{226}Ra is highest in plant area(36Bq/Kg) and lowest in residential area(10.9Bq/Kg). ^{40}K highest in residential area(977Bq/Kg)and lowest in open area(452Bq/Kg). ^{232}Th is highest in plant area(47.9Bq/Kg) and lowest in residential area(30.3Bq/Kg).From table(6) ^{226}Ra is highest in open area(31.7Bq/Kg), and lowest in residential area(14.6Bq/Kg). ^{40}K is highest in plant area(1550Bq/Kg) and lowest in residential area(633Bq/Kg). ^{232}Th is highest in open area(32.9Bq/Kg) and lowest in plant area(25.2Bq/Kg).From table (7) ^{226}Ra is highest in one open areaS_{21}(30.9 Bq/Kg), lowest in residential area (8.8 Bq/Kg). ^{40}K, highest in open areaS_{22} (468Bq/Kg), lowest, residential area (380 Bq/Kg). ^{232}Th, highest in open area S_2(45.7Bq/Kg), lowest in residential area(18.6 Bq/Kg).From table (8)^{226}Ra, highest in residential(17.2Bq/Kg), lowest in open(12.6Bq/Kg). ^{40}K, is highest in residential(810Bq/Kg), lowest in open(482Bq/Kg). ^{232}Th, highest in plant(28.9Bq/Kg), lowest in open(23.3Bq/Kg).From table (9) the area of the two samples S_{26} and S_{27}, is an open area with the activity concentration of ^{226}Ra in S_{26}(14.7Bq/Kg), in S_{27}(6.7Bq/Kg). For^{40}K, the corresponding values are (550Bq/Kg) and (320Bq/Kg) respectively. For ^{232}Th the values are (2.7Bq/Kg) and (5.1Bq/Kg). From table (10) ^{226}Ra is highest in plant(37Bq/Kg), lowest in both open and residential areas (0Bq/Kg). ^{40}K, is highest in plant (850Bq/Kg), lowest in residential(214Bq/Kg). ^{232}Th, is highest in plant (4.4Bq/Kg), lowest in residential (1.3Bq/Kg).From the above discussion it concluded that the background of the area of the samples, whether being there is no relationship between the activity concentration according to the area in all locations.

From the discussion of the results of all locations showed that the average concentration of ^{40}K is higher than the average concentrations ^{226}Ra and ^{232}Th

In general, the average annual effective dose from this study is found to be, 0.06mSv/Y, 0.25mSv/y outdoor and indoor respectively, these values when compared with the corresponding average values worldwide 0.07mSv/y outdoor and 0.41mSv/y indoor, there are found to be less .From this study it is found that the average external radiation hazard index for Kassala town is 0.29 which is less than "1

Table(1): The Activity concentration(Bq/kg), (Alkara)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_1	30	1880	31
S_2	37	1430	59
S_3	14.7	1140	13
Average	27.23	1483.33	34.33

Table(2):The Activity concentration(Bq/kg), (Shamal Alhalanga)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_4	6.7	320	5.1
S_5	14.7	550	2.7
S_6	17.8	600	4.7
Average	13.07	490	4.17

Table(3):The Activity concentration(Bq/kg), (Mokram Sharq)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_7	13.7	750	2.6
S_8	15.2	470	3.3
S_9	23.3	700	4.9
Average	17.4	640	3.6

Table(4):The Activity concentration(Bq/kg), (Alsomaa)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{10}	19.5	920	1.9
S_{11}	12.7	442	14.6
S_{12}	27.2	1320	30
Average	19.8	894	15.5

Table(5):The Activity concentration(Bq/kg), (Awitala)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{13}	10.9	977	30.3
S_{14}	36	465	47.9
S_{15}	30.5	452	43.5
Average	25.8	631.33	40.57

Table(6):The Activity concentration(Bq/kg), (Alengaz Sharq)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{16}	31.7	1250	32.9
S_{17}	25	1550	25.2
S_{18}	14.6	633	30.6
Average	23.77	1144.33	29.57

Table(7):The Activity concentration(Bq/kg), (Alsabeel)

Sample code	^{226}Ra Bq/kg	^{40}K Bq/kg	^{232}Th Bq/kg
S_{19}	8.8	380	18.6
S_{20}	9.9	416	20.3
S_{21}	30.9	452	45.7
S_{22}	11	468	22.8
Average	15.15	429	26.85

Table(8):The Activity concentration(Bq/kg),(Sharq Almatar)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{23}	15.7	750	28.9
S_{24}	12.6	482	23.3
S_{25}	17.2	810	28.8
Average	15.17	680.67	27

Table(9):The Activity concentration(Bq/kg) (Hamasayeb)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{26}	14.7	550	2.7
S_{27}	6.7	320	5.1
Average	10.7	435	3.9

Table(10):The Activity concentration(Bq/kg),(Alkurmota)

Sample code	^{226}Ra	^{40}K	^{232}Th
S_{28}	N.D	430	1.6
S_{29}	37	850	4.4
S_{30}	N.D	214	1.3
Average	12.33	498	2.43

*N.D:Not detected

Table(11):The Activity concentration(Bq/kg),Overall the Town

The element	^{226}Ra	^{40}K	^{232}Th
Average	18.19	732.37	19.56
Max	37	1880	59
Mini	6.7	320	1.3

Table(12): Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alkara)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq}Bq/Kg	H_{index}
S1	110.98	0.14	0.54	219.09	0.59
S2	112.36	0.14	0.55	231.48	0.63
S3	62.18	0.076	0.31	121.07	0.33
Average	95.17	0.12	0.47	190.53	0.52

Table(13):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Shamal Alhalanga)

Sample code	**D_R(nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_4	19.51	0.02	0.095	38.63	0.1
S_5	31.36	0.04	0.15	64.01	0.17
S_6	36.08	0.04	0.18	11108.71	0.29
Average	28.98	0.03	0.14	70.45	0.19

Table(14):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Mokram Sharq)

Sample code	**D_R (nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_7	39.17	0.05	0.19	75.17	0.20
S_8	28.61	0.04	0.14	56.11	0.15
S_9	42.91	0.05	0.21	84.21	0.23
Mean	36.9	0.05	0.18	71.83	0.19

Table(15) absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alsomaa)

Sample code	**D_R (nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_{10}	48.52	0.06	0.24	93.06	0.25
S_{11}	33.12	0.04	0.16	67.61	0.18
S_{12}	85.73	0.11	0.42	171.74	0.46
Mean	55.79	0.07	0.27	110.80	0.29

Table(16):Absorbed dose rate, annual effective dose (indoor/outdoor), radiation hazard index and radium equivalent, (Awitala)

Sample code	**D_R (nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_{13}	64.08	0.079	0.31	129.46	0.35
S_{14}	64.95	0.079	0.32	140.3	0.38
S_{15}	59.21	0.073	0.29	127.51	0.34
Average	62.75	0.077	0.31	132.42	0.36

Table(17):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (AlengazSharq)

Sample code	**D_R (nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_{16}	86.64	0.11	0.42	174.99	0.47
S_{17}	91.41	0.11	0.45	180.39	0.49
S_{18}	51.62	0.06	0.25	107.1	0.29

Mean	76.56	0.09	0.37	154.16	0.42

Table(18):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (Alsabeel)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq}Bq/Kg	H_{index}
S_{19}	31.15	0.04	0.15	64.66	0.17
S_{20}	34.18	0.04	0.17	70.96	0.19
S_{21}	60.73	0.07	0.29	131.06	0.35
S_{22}	38.37	0.05	0.19	196.65	0.22
Mean	41.11	0.05	0.2	115.83	0.23

Table(19):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent, (SharqAlmatar)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	H_{index}	Ra_{eq}Bq/Kg
S_{23}	55.98	0.07	0.27	0.31	114.78
S_{24}	39.99	0.05	0.19	0.22	83.03
S_{25}	59.12	0.07	0.29	0.33	120.75
Average	51.69	0.06	0.25	0.29	106.19
Sample code	**D_R (nGy/h)**	**H_E out mSv/y**	**H_E in mSv/y**	**Ra_{eq}Bq/Kg**	**H_{index}**
S_{26}	31.36	0.04	0.15	60.91	0.47
S_{27}	19.52	0.02	0.095	38.63	0.10
Average	25.44	0.03	0.12	49.77	0.29

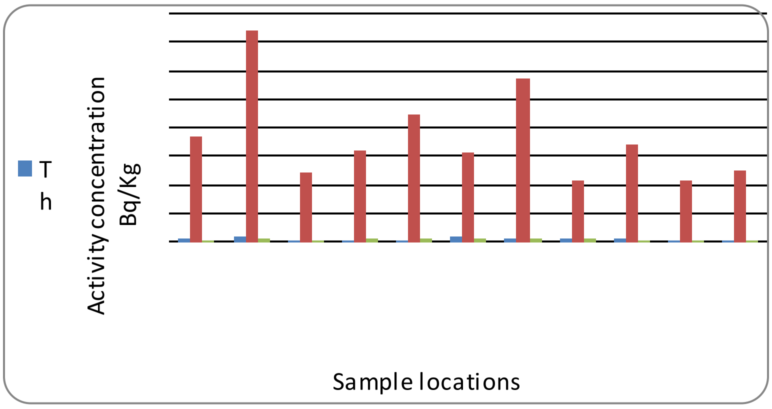
radiation hazard index and radium equivalent, (Hamasayeb)

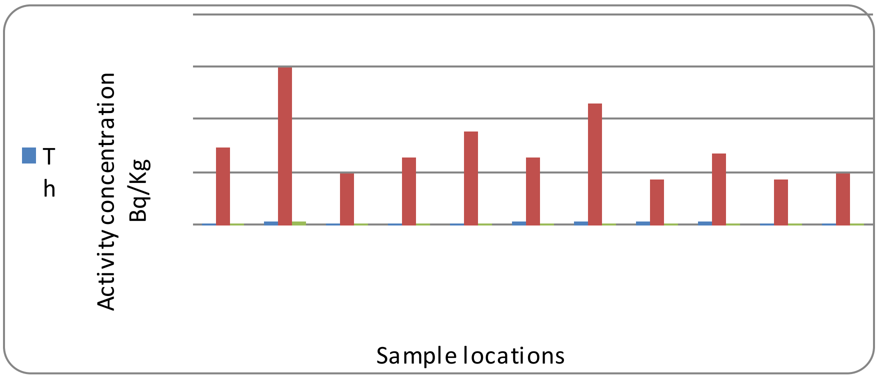
Table(20):Absorbed dose rate, annual effective dose (indoor/ outdoor), radiation hazard index and radium equivalent(Alkurmota)

Sample code	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq}Bq/Kg	H_{index}
S_{28}	18.89	0.02	0.09	35.39	0.09
S_{29}	55.19	0.07	0.27	108.74	0.29
S_{30}	9.71	0.01	0.05	18.34	0.05
Average	27.93	0.03	0.14	54.16	0.14

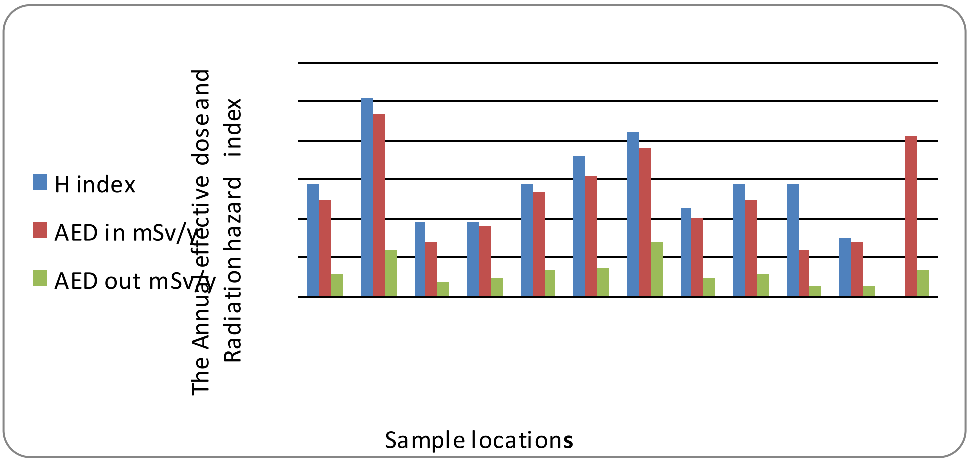
Table(21): Absorbed dose rate, annual effective dose (indoor/ outdoor) , radiation hazard index and radium equivalent for the Town

Doses	D_R (nGy/h)	H_E out mSv/y	H_E in mSv/y	Ra_{eq}Bq/Kg	H_{index}
Average	50.75	0.06	0.25	107.82	0.29
Max	112.36	0.14	0.42	231.48	0.59
Mini	9.71	0.01	0.05	18.34	0.05

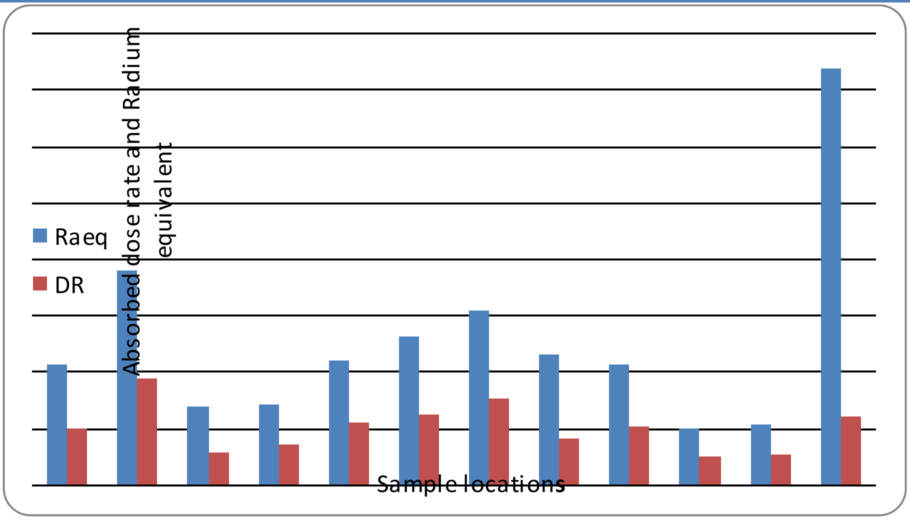




Figure(1):The Histogram representing the average activity concentration for the locations and the town



Figure(2):The annual effective dose and radiation hazard index for the different locations, the town and worldwide



Figure(3):The absorbed dose rate and radium equivalent for the different locations,the town and worldwide

Discussion

Since the general aim of this study is to measure the concentration of natural radioactivity in soil samples in Kassala town and the special objective is to determine the activity concentration of the elements ^{226}Ra, ^{232}Th and ^{40}K ,using gamma-ray spectrometry and calculate the absorbed dose rate, annual effective dose and estimate the radiological hazard from the soil of the town according to the standard. The average concentration of all elements in the study is less than the average worldwide except the element ^{40}K.

The mean absorbed dose rate was calculated and compared with the corresponding worldwide average(which is found to be less than the worldwide average).

The annual effective dose was estimated and found to be(outdoor) and (indoor), while are less than the worldwide and the radiation hazard index was found to less than "1"

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